Peeling Back the Layers of Solar Cells: The Physics, Chemistry, and Biology of Solar Energy

Andrew Saydjari
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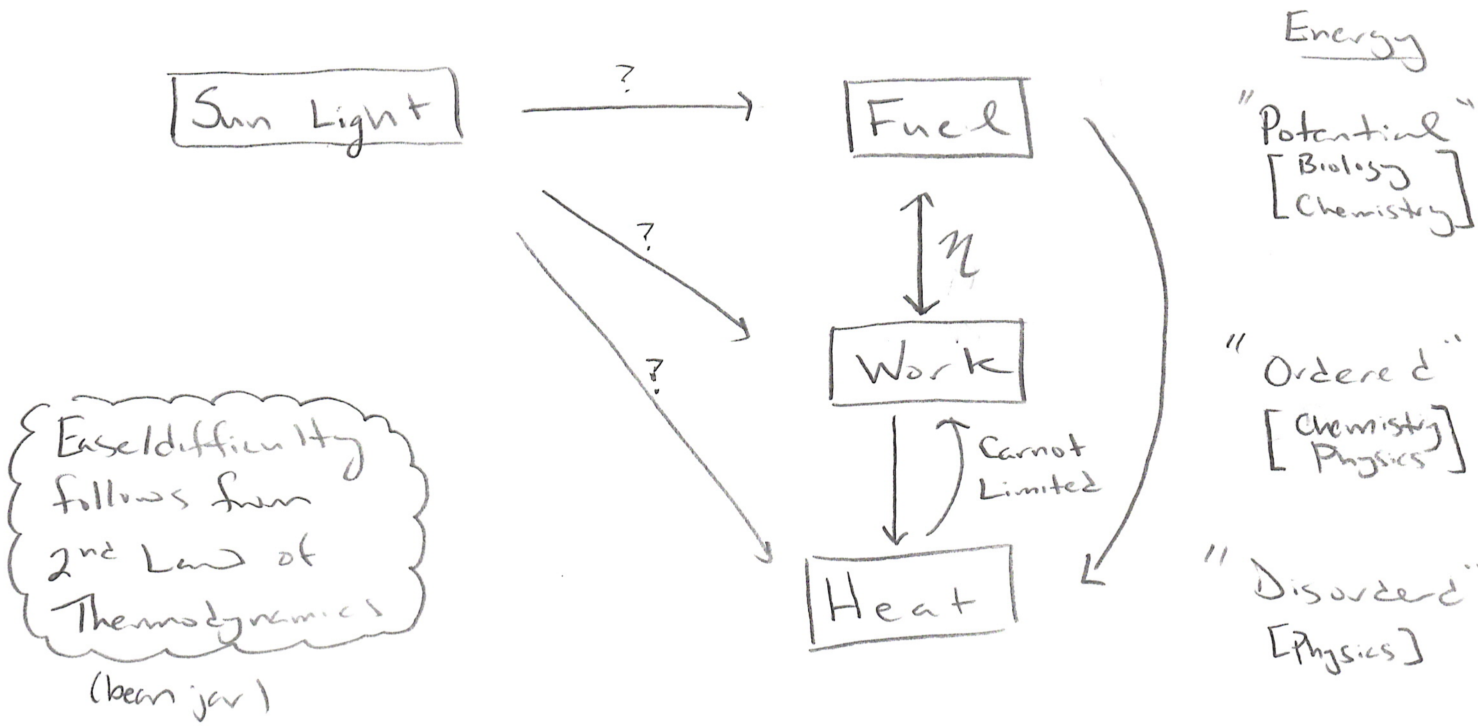
Overview

* 0.1% incident solar output = total consumption at earth *



Heat

Solar Thermal Collectors (black t-shirt) [50-70%]

- CuO on Cu
- Black Cr on Ni-plated Cu

→ App. Boil H_2O

[?] Why not paint?

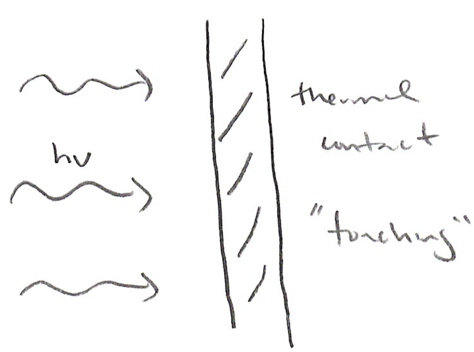
Kirchhoff's Law of Thermal Radiation $\alpha = \varepsilon$ (∄ T → inf E draw)

$\Rightarrow \alpha(\text{vis}) > \varepsilon(\text{IR})$

Schematic:

Absorb
↓
Use

"easy"



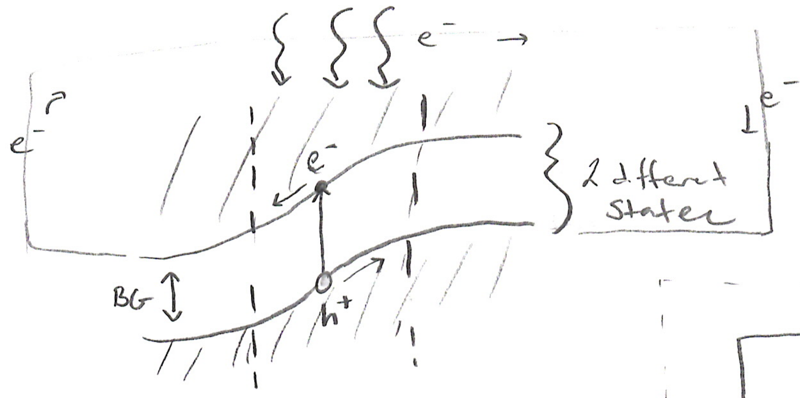
1 Layer

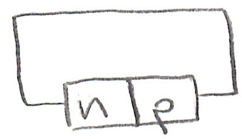
Work

Semiconductors "Photovoltaic"

Schematic:

Absorb
↓
Sep e^-
↓
Use





2 Layers

electrical contact

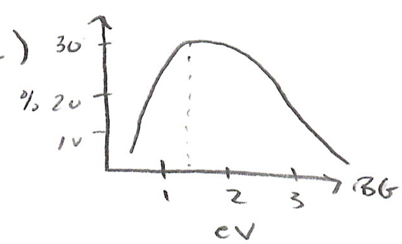
$E = h\nu = \frac{hc}{\lambda}$ [?] Peak of Solar spectrum

key:

1. Only absorb $h\nu$ if $E > BG$
2. All $E - BG$ lost (usually, multiexciton generation for exception)

[?] Tradeoff, which do we want? ↑BG or ↓BG

↳ Shockley-Queisser Limit (+ physics of losses in SC)
- 1 layer 33.7% [28 %] ⟶ ∞ layers 86.8% [46 %]



- Perovskites - specific crystal structure of SC
  - cheaper, better match BG* [21 %]
  - degrade easily

App: Roof panels [14-17%]

END CLASS 1

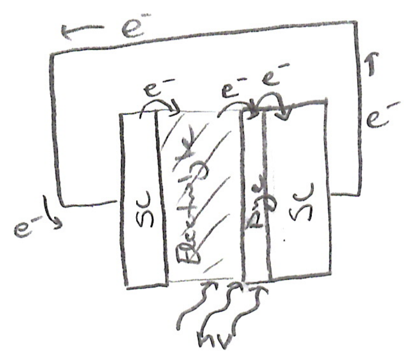
Dye-Sensitized Solar Cells

Schematic:

Absorb
↓
Sep e^-
↓
use

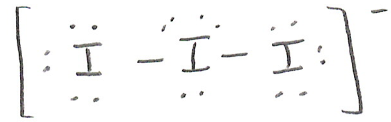
4 Layer

different phases
electrical
contact



Redox-Couple:

$I_3^- + 2e^- \rightleftharpoons 3\,I^-$



[?] Why need electrolyte?

- Dye $e^- - h^+$ not seperate well ("exitons")
  - → thin layer → push e^- into SC
  - * no $e^- - h^+$ recombine

(Welectrolyte ~~permeable~~)

Main difference is mobility of e^-!!!

Ex: $Ru(bpy)_3$ [11.5%]

- low light operation, flexible
- liquid electrolyte

Fuel

Biology [0.1 - 0.3%]

$$6\,CO_2 + 6\,H_2O \xrightarrow{hv} C_6H_{12}O_6 + 6\,O_2$$ [?]

- light-activated reaction - moves e^- w/in molecule "radical"
  - → ADP / NADPH → Power protein mechanisms
  - (neither arrow well understood)

Absorb
↓
Sep e^-
↓
Store

N Layers / e^- jumps

where N is very, very large

Solar Electrolysis (split H_2O) [30%]

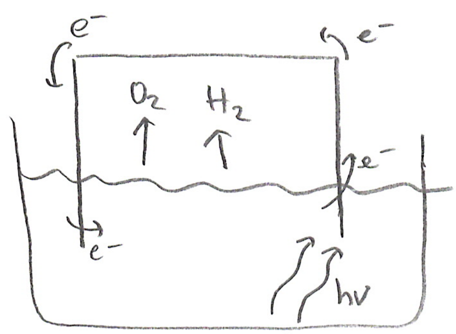
$2H_2O \rightarrow 2H_2 + O_2$ $\Delta G = 286$ kJ/mol (taken E)

- catalyst to oxidize H_2O
  - photocatalyst is reactive in excited state (very careful design molecule)

App: H_2 fuel cells
- $2°$ η, explosive

Schematic:

Absorb
↓
Sep e^-
↓
Store



3 Layers:
catalytic coating

★ Here liquid between electrodes is active in reaction. ≠ Electrolyte couple just a transport mechanism.

Solar Thermal Cells

key: Store E w/in molecule by changing its orientation/ e^- density

$h\nu$ ⇝ low E molecule ⇄ high E molecule → heat

- Electrocyclic: norbornadiene → quadricyclane

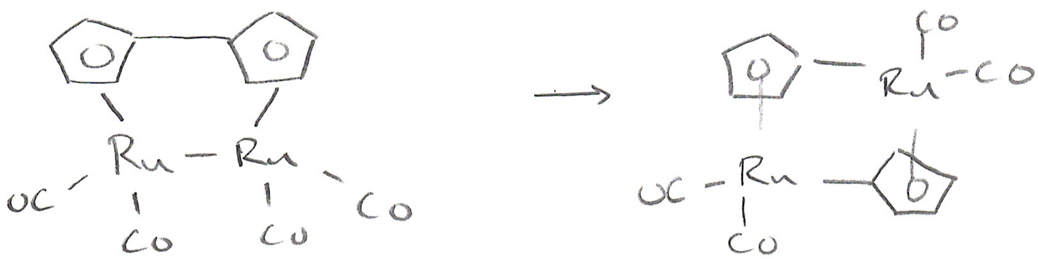
(model)

3-mem ring strain

- Double Bond Isomerization: azobenzene [0.4%]

[?] crowded v apart

• Ligand Reorientation (breaks C-C bond)



(fulvalene) tetracarbonyl-diruthenium

App: no electrical grid (|| solar collectors), but also able to store
* "recyclable" fuel

Summary

- Always think about goal on hierarchy, and how going to get there
  - Ex: electrodes for 2 very different cells
- Cost to maintaining order in the efficiencies
  - H_2 exception b/c coupling η (but very promising)

Fuel	Work	Heat
• H_2 • STC -electrocyclic -double bond -ligand • biology	• Semiconductors - Perovskites • DSSC	• Solar Thermal Collectors

← Complex
Apparatus/Goal